Evaluating wind technicians performance on safety critical rescue steps

Lawani, Kenneth; Hare, Billy; Cameron, Iain

Published in:
Proceedings of the ICE - Management, Procurement and Law

DOI:
10.1680/jmapl.18.00002

Publication date:
2019

Document Version
Author accepted manuscript

TITLE:

EVALUATING WIND TECHNICIANS PERFORMANCE ON SAFETY CRITICAL RESCUE STEPS

AUTHORS:

Kenneth Lawani[1], Billy Hare[1], & Iain Cameron[1]

[1]*Department of Construction and Surveying, Glasgow Caledonian University, Cowcaddens Road, G4 0BA, UK*

Dr Kenneth Lawani; Lecturer in Construction Project Management - Kenneth.Lawani@gcu.ac.uk

Professor Billy Hare; Deputy Director of the Built Environment Asset Management (BEAM) Research Centre - B.Hare@gcu.ac.ukk

Professor Iain Cameron; Dean for the School of Engineering and Built Environment - I.Cameron@gcu.ac.ukk

EVALUATING WIND TECHNICIANS PERFORMANCE ON SAFETY CRITICAL RESCUE STEPS

Abstract:

Purpose: This paper reports the results of an analysis of a subset of data from a larger study on skill decay. It evaluates the performance levels of wind technicians at one and three months on safety critical steps using Situational Judgement Tests (SJT) and Job Knowledge Tests (JKT) to assess their emergency rescue and evacuation proficiency.

Design/methodology/approach: The research design is a repeat measures study (longitudinal), using SJT and JKT to assess job-specific knowledge; the extent of knowledge technicians acquired regarding effective and ineffective courses of action in job-related situations; assessing a variety of situations; and measure various kinds of procedural knowledge such as critical decision-making situations. It measured procedural knowledge in addition to aspects of declarative knowledge and fluid abilities and this was considered as a good predictor of performance for wind technicians.

Findings: The results show that rescue and evacuation skills decay at one and three months after the wind turbine rescue and evacuation training with 47% and 20% of technicians experiencing such decay in their skills and knowledge. However, relying only on the high knowledge proficiency gives a false sense of security in terms of overall procedural competence of the technicians. This study demonstrates to what extent new technicians struggle to sustain their competence without any form of practice.

Practical implications: This study reaffirms that the commonly used rescue device lack task steps that are cued by the previous sequence of steps or by the equipment. Therefore, technicians tend to easily forget some of the procedural and safety critical steps that are inherent to the device. These findings have practical implications for activities involving rescue and evacuation of workers, e.g. crane driver rescue.

Research implications: The implementation of SJT and JKT in this study indicates that skill decay takes place within the first four weeks after acquisition. Likewise, job knowledge is more resistant to decay as compared to skill tasks over the three months retention time frame for both refresher and new wind technicians.

Originality/value: The results of this paper build on existing knowledge by extending SJT and JKT theory to field-based applications within the wind energy.

Keywords: Health & safety; Knowledge management; Education & training; Safety & hazards

Paper type: Research paper

Introduction

The retention of skill after episodes of non-use or non-practice has significant consequences when the learned skills are not applied over a long period of time after training. When skills and knowledge are not used over an extended period, they gradually deteriorate (**Arthur *et al*. 2007; Arthur Jr, *et al*. 2010; Kluge & Frank 2014; Arthur Jr, et al. 2013**). This is particularly dangerous in situations where workers are initially trained on skills and knowledge that they may not have the opportunity to routinely perform. Lack of inadequate evaluation of performance can potentially lead to inaccurate identification and prediction of skill decay. Workers, in the context of this paper, refer to wind technicians involved in the construction and maintenance of wind turbines (**returning or refresher technicians and new or first-time technicians**).

The safe and competent use of the constant rate descender requires specific operating skills. These wind turbine rescue and evacuation devices are commonly used for rescue of self and casualties during accident or emergency situations whilst working in a Wind Turbine Generator (WTG). Technicians tend to easily forget the procedural steps associated with these wind turbine rescue devices because it requires multiple steps to successfully deploy the devices and the steps are not cued by preceding steps **(Lawani 2015).** Correctly reacting to unusual rescue situations will require the technicians to have the requisite skills and detailed understanding of the operating theory of the rescue and evacuation device **(Reason 2008; Cesta et al. 2014)**. Most importantly, technicians require the skill and knowledge-based rescue training to understand the functional requirements of the different rescue and evacuation devices, thus equipping them to deal with different emergency scenario. This paper reports on the results of an analysis of a subset of data from a larger study on skill decay. It evaluates performance levels of wind technicians at one and three months on some safety critical steps by implementing 'Situational Judgement Tests' (SJT) and 'Job Knowledge Tests' (JKT) to assess their proficiency.

The Health and Safety at Work etc Act 1974; Provision and Use of Work Equipment Regulations 1998; Management of Health and Safety at Work Regulations 1999; all require secured and effective emergency response to incidents/accidents with the likelihood of affecting persons and this study extends this relationship to onshore/offshore wind turbine installations. Equally, initial response during emergency rescue and evacuation from a WTG is dependent on the competence and skill set of technicians that are involved.

Wind technicians undergo basic level height safety and rescue training endorsed by RenewableUK (RUK) and the Global Wind Organisation (GWO). The industry assumes that technicians should be able to retain their competence in a fluid work environment with up-to-date knowledge and skills over a two year period before embarking on prescribed refresher training. Although, workplace and refresher training programs have both been identified as having significant roles in maintaining knowledge and skills; a common limitation is when such training fails to address the requisite skill. Therefore, this study

adopts a quick and effective means of evaluating technicians' knowledge and skill. Regulations such as the Construction (Design and Management) Regulations 2015 (CDM) emphasises the significance of skill, knowledge, training, qualifications and experience which are core to efficiently carrying out emergency rescue and evacuation. Also, the Personal Protective Equipment at Work Regulations 1992 (PPE) requires that information, instruction and training must be provided to users and that the extent of these reflects the complex nature of the equipment involved. Such training and instructions will be particularly rigorous for items such as specialised PPE e.g. the emergency constant rate descender.

Skill and Knowledge Decay

Skill is a term describing the sequences of learned actions that are entrenched in the context of other on-going events. Skill acquisition has been described in terms of stage or phase designations defining different aspects of the learning process; see **(Anderson 1983; Adam 1987; Kluge *et al*. 2010; Kim *et al*. 2013)** while skill retention signifies the ability to perform following a break from a learning period **(Richardson-Klavehn & Bjork 1988; Kim et al. 2007; Kim et al. 2013; Kluge et al. 2016)**. Therefore, evaluating the skill and knowledge performance of technicians on safety critical recue steps after a period of time could potentially reveal the true effectiveness of manipulations executed during acquisition. The process of evaluating such skill could be both quantitative and qualitative changes in behaviour. The quantitative changes come in the form of rapid anomalies in numerically measurable aspects of performance rate. A decay in the time taken by a technician to execute a particular rescue step as well as the number of errors committed whilst doing so are likely to be obvious, alongside, increases in the amount of work completed within a given period **(Annett 1991; Kluge et al. 2016; Kim et al. 2013; Kluge & Frank 2014)**. Qualitative changes could be associated to inconspicuous routines and habits of technicians and the absence of more obvious cues associated with the rescue kits.

Rationale for SJT and JKT

The Situational Judgement Test (SJT) for this study was developed as a job test to reflect the realistic descriptions of rescue and evacuation procedures. SJTs assess individuals' reactions to a number of hypothetical role relevant scenarios reflecting potential conditions that participants come across in their target role, (**Patterson et al. 2016**). SJT is a measure of procedural knowledge in a specific domain. It is a measurement tool useful for evaluating job-related competencies and skills; and it is considered as a step detached from direct observation; and built on the behavioural consistency logic; (**Lievens *et al.* 2008; Lievens & Sackett 2012**; **Lievens & De Soete 2012**). This study therefore implemented SJT to appraise procedural and some aspects of declarative knowledge and fluid skills. This was considered as an auxiliary and valid evaluation of performance for wind technicians lacking the opportunity for routine hands-on practice after formal training. Furthermore, the SJT assessment for this study mimicked the realistic process of carrying out a rescue using visual

2D pictographs of the rescue device. The procedural steps were randomised in order to measure judgement skills directly related to the process of hands-on rescue; (**Motowidlo *et al*. 1990**).

This study assumed that performances of wind technicians involved in the SJT assessment could identify elements of lack of retention in safety critical steps related to emergency rescue and evacuation. **Motowidlo *et al*. (1990**) consider SJTs as low-fidelity imitations because they do not require participants to display actual behaviour but instead confront them with written descriptions of realistic job situations. **Sackett *et al*. (2001**) and **Whetzel & McDaniel (2009**) noted that most low-fidelity imitations (SJTs and JKTs) for assessing participants with practical experience could build more on participants' existing foundation of knowledge; **(Anderson et al. 2017).**

Job Knowledge Test (JKT) was useful in assessing technicians' declarative knowledge, i.e., knowledge of facts, rules, and principles; (**Kanfer & Ackerman 1989**; **McCloy *et al*. 1994; Patterson et al. 2016; Zierke 2014)**. The JKT for this study required technicians to demonstrate their theoretical understanding and knowledge of working at height; rescue and evacuation as a good indicator for evaluating knowledge performance. The SJT and JKT assessments covered aspects such as:

- ✓ dangers of working at height;
- ✓ how to assess the hazards and implement effective controls;
- ✓ how to use restraint, positioning and fall arrest systems;
- ✓ selecting proper anchor points;
- ✓ practical climbing on ladders using fixed vertical safety systems;
- ✓ recognising and dealing with suspension trauma;
- ✓ planning for emergency procedures;
- ✓ features and limitations of the rescue equipment being used; and
- ✓ how to rescue a suspended colleague from an in-reach or out-of-reach situation.

The SJT/JKT was practical to administer to wind technicians and the identification of the safety critical task steps and the correct performance sequence of the constant rate descender were mutually identified by the author and RUK accredited specialist training company. The assessment was calibrated by adopting the cumulative sum approach (**Bohm & Hackl 1996**) based on correct rescue and evacuation performance steps. Therefore, both SJT (procedural knowledge) and JKT (declarative knowledge) assessed job-specific knowledge; and measured various kinds of procedural knowledge such as critical decision-making situations.

Reliability of SJT and JKT

The research embarked on a pilot study with 15 wind technicians to explicitly refine and develop the research instruments **(Gillham 2000)**, assess degrees of observer bias **(Hróbjartsson et al. 2013; Hammersley & Atkinson 1995)** and use the experience to review

questions and adapt the study approach. The pilot study analysed the reliability of the instruments as part of the preliminary phase. The internal reliability using 'Cronbach's alpha' of 0.810 suggested very good internal consistency reliability for the scale (**Pallant 2011)**. This is within the range proposed by **McDaniel *et al.* (2001**). Therefore, this study implemented online assessment with the 2D pictographs of the rescue device for the SJT and JKT assessments.

Wind Technicians & Type of Training

The basic height rescue and evacuation training is mandatory for wind technicians that access and work both onshore and offshore in WTG during stages of construction, commissioning, operations and maintenance of wind turbines. Therefore, assessing the technician's capability to correctly and procedurally execute the acquired rescue skills after periods of non-practice is essential to avoid complications during times of emergency rescue. Participants for this paper comprise of '**returning**' and '**first-time**' wind technicians registered to undergo the two-day mandatory RenewableUK (RUK) and Global Wind Organisation (GWO) approved work at height and rescue training, (**RenewableUK 2014**).

Sources of Data

The data for this paper was collected by the researcher after undergoing training and mentoring with the RUK approved height safety and rescue specialist training company.

Description of applied Research Method

This study initially recruited 82 wind technicians with varying years of on-the-job experience, skill, training and competence (0 to ≥ 10 years) which is assumed to represent the wider population. The rationale for engaging these number of technicians was to accommodate drop-out effects in longitudinal research (**de Vaus 2001**; **Creswell 2014)**. Drop-out are often associated with longitudinal research most especially when there are no incentives for participants to continue over a period of time as was the case for this study. Therefore the longitudinal study focused on participants that took part in the whole assessment session. The wider study collected data before training (**pre-acquisition**); during training (**acquisition**); immediately after training (**peak acquisition**) and this paper focuses on the post training data (**retention**) at one and three month periods.

The rationale for adopting the timeframe of one and three months was based on research that non-routine complex procedural tasks are highly subject to forgetting after a relatively short period of non-practice, **(Wixted & Ebbesen 1991; Wixted 2004**). Also, there are no standardised timeframe set out for the evaluation of skill retention as observed in the works of (**Sauer et al. 2000; Arthur Jr. et al. 2002; Kim et al. 2007; Meador & Hill 2011; Kluge & Frank 2014)** which signifies that evaluations are established on individual capability. Similarly, based on the peripatetic nature of wind technicians and the prescribed refresher timeframe of two years by RUK and GWO, this study objectively adopted an early refresher timeframe of one and three months predicting that technicians would not have embarked

on any rescue and evacuation training or practice drills after formal training. Therefore, 30 wind technicians fully participated in the skill and knowledge assessments from pre-acquisition to post-acquisition phases accounting for drop-out effects.

The wind technicians were presented with randomised procedure of how to use the rescue device for evacuation purposes. They were required to procedurally simulate lifting and lowering of a casualty involved in an accident over a short distance by implementing the correct sequence. These procedural descriptions are requirements of the formal training that wind technicians will typically come across during rescue and evacuation of casualties involved in accidents within the WTG.

Measures and Data Collection

Retention measures were conducted online at one and three months using structured Job Knowledge Test (JKT) and Situational Judgment Tests (SJT) for knowledge and skill assessment; by adopting the approved tests by the regulating body. The SJT enabled wind technicians to recognise the specific recue device (from 2D pictograph) which is one of several rescue devices they get trained on. The SJT also helps the technicians to identify and simulate the correct procedural step-by-step method of using the rescue device; presented as written description of realistic rescue and evacuation operation.

The JKT covered aspects such as introduction to personal fall protection; general safety requirements for work in a WTG; procedures for access/egress and working within the turbine; selection, care and maintenance of equipment; restraint, work positioning and fall arrest systems; principles of continuous attachments; types of anchorage in WTG; suspension syncope and emergencies based on the RUK prescribed testing for technicians.

Findings:

Situational Judgement Tests (SJT) Results

The SJT assessment had 10 procedural steps needed to carry out rescue. These steps were randomised at one and three month retention assessments to evaluate if technicians could recall the sequence. **Figure 1** shows the performance change at one month and three month retention measures. The study applied a limit state performance of 70% as a benchmark of good practice **(Lawani et al. 2015)**. The result indicated that 14 wind technicians performed below this 70% benchmark at one and three months retention while 16 technicians performed at ≥ 70% benchmark.

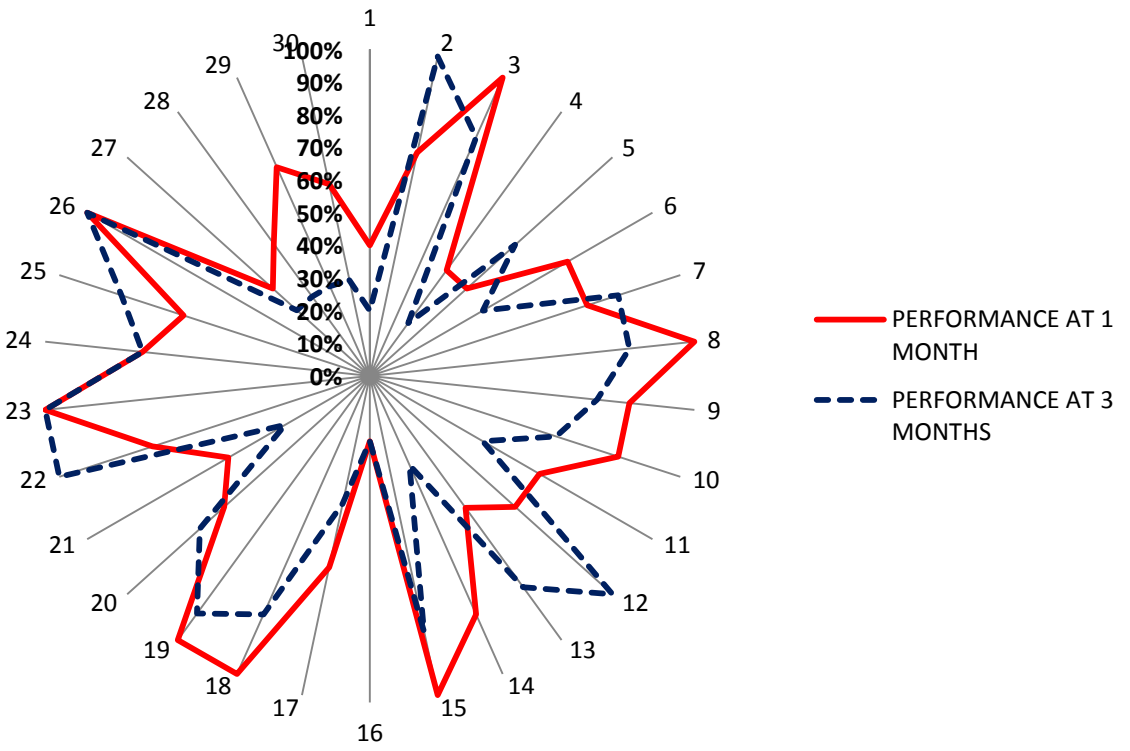

Figure 1: Percentage skill performance using 70% as limit state measure for 30 technicians at one and three month retention

Four technicians had performances of <70% at one month retention but showed improvements in their performance at three months retention (≥70%). These four technicians were identified as those that had undergone the refresher training meaning they have previously been trained on the rescue device which could probably be the precursor for the performance spike. Similarly, the 2D pictograph incorporated as part of the evaluation process could have positively triggered the returning technicians' recall of the implementation of the rescue device. Conversely, four technicians had performance dip from ≥70% to <70% and these were identified as new technicians that have undergone the rescue and evacuation training for the very first time. Their performance dip could be as a result of their lack of competence and non-practice with the rescue device. This indicates that skill decay is pervasive at one and three months after the formal rescue and evacuation training with new technicians. It also indicates that the highest degree of skill decay is predominantly within the first four weeks after training and then thereafter.

The wind technicians were assessed on five safety critical steps (**3, 5, 7, 8 and 9**) to determine their susceptibility to making errors and the tendency to further complicate the rescue process. These steps include: attaching control rope to friction stud; locking off the CRD (brake) and turning the plunger on the side to prevent free fall; pushing the silver ball bearing button to close up wheel; unlocking the CRD (brake) by off weighting the wheel and pulling out the plunger quarter turn; and finally folding the handle back into groove to prevent accident. The average performance from the data indicates that the technicians showed no improvement in their ability to successfully execute task steps **3, 5, 7, 8 and 9** at

one month and three months retention intervals, see **Table 1** and **Figure 2.** These five safety critical steps are fundamental to the rescue process, i.e. lifting and lowering a casualty from an in-reach and an out-of-reach environment.

Table 1: Technicians' error rates on safety critical skill tasks at 1 and 3 month retention

Safety Critical Skill Steps	Technicians at 1 Month Retention		Technicians at 3 Months Retention	
	Tech. Right	Tech. Wrong	Tech. Right	Tech. Wrong
Q3: Attach control rope to friction stud	**16**	**14**	**16**	**14**
Q5: Lock of the CRD (brake) turning the plunger on the side to prevent free fall	**23**	**7**	**17**	**13**
Q7: Push silver ball bearing button to close up wheel	**11**	**19**	**9**	**21**
Q8: Unlock CRD (brake) by off weighting the wheel & pulling out plunger quarter turn	**11**	**19**	**11**	**19**
Q9: Fold the handle back into groove	**8**	**22**	**6**	**24**

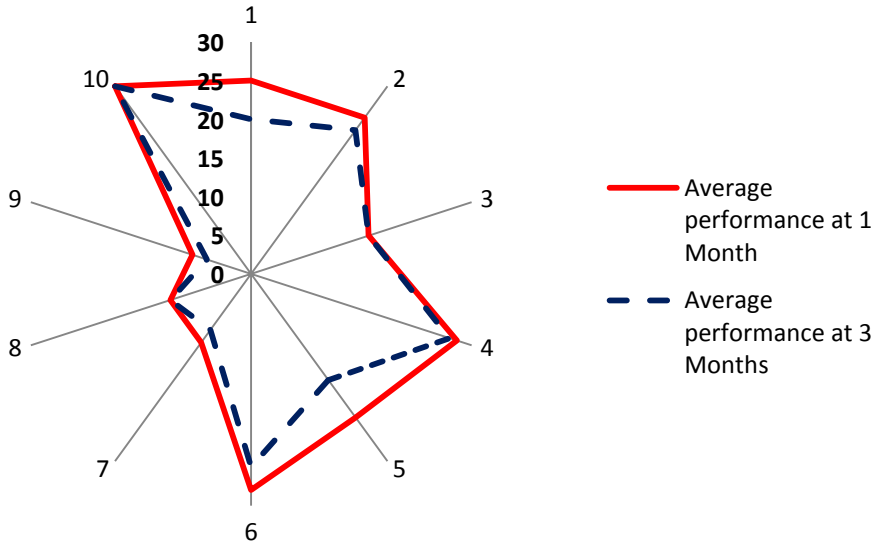

Figure 2: Performance output per skill step at one and three month for 30 technicians

Figure 2 shows the performance output and safety critical steps that technicians displayed no improvement. Fourteen (14) technicians could not correctly execute task step 3 at one and three months; i.e. attaching control rope to friction stud. Seven (7) and 13 technicians could not correctly execute task step 5 at one and three months; i.e. locking the device using the plunger on the side of the device to prevent free fall of casualty. Nineteen (19) and twenty-one (21) technicians could not successfully execute task step 7 at one and three months i.e. closing up the device wheel using the silver ball bearing. Nineteen (19) technicians could not execute task step 8 at one and three months; i.e. unlocking the brake

system of the constant rate descender (CRD) by off weighting the wheel & pulling out plunger quarter turn. Twenty-two and twenty-four technicians could not successfully execute task step 9 at one and three months; i.e. folding the handle back into groove to prevent accidental contact with the rescuer and casualty and this could further lead to a more complicated rescue scenario. The technicians consistently showed no improvement in their performance on these five safety critical steps which are considered fundamental to a successful execution of rescue and evacuation of a casualty using the device.

These safety critical steps make up part of the procedural process not cued by the device and when forgotten; could further complicate the rescue process, the safety of the casualty and the rescuer. These further confirm that some safety critical steps regarding the use of the rescue device are amenable to the impact of skill decay at one and three month retention intervals. This indicates that with the passage of time there is a pattern of decay regarding the correct implementation and sequencing of rescue and evacuation by wind technicians in the absence of hands-on practice.

Job Knowledge Tests (JKT) Results

The design of the JKT assessment had 15 knowledge questions for assessing technicians' declarative knowledge of rescue and evacuation. These questions were randomised at retention intervals of one and three months to evaluate if technicians could recall the correct answers. The 70% limit state performance was also implemented and **Figure 3** shows performance scores at one and three month retention for 30 wind technicians. It identifies that 24 wind technicians performed above ≥70% while six were below the specified limit state. The performances in the JKT assessment also indicate some convergence in the scores over this timeframe. Three technicians performed below the 70% limit state at one month retention and above 70% at the three month retention assessment. These were technicians that had undergone the refresher training exercise. Similarly, three technicians that performed above the 70% limit state in the one month retention test performed below the 70% limit state at three months retention and these were identified as technicians that had undergone the training for the very first time. Overall, this study identified a pattern and consistency of performance regarding the JKT test which reveals higher retention compared to skill performance at one and three month retention.

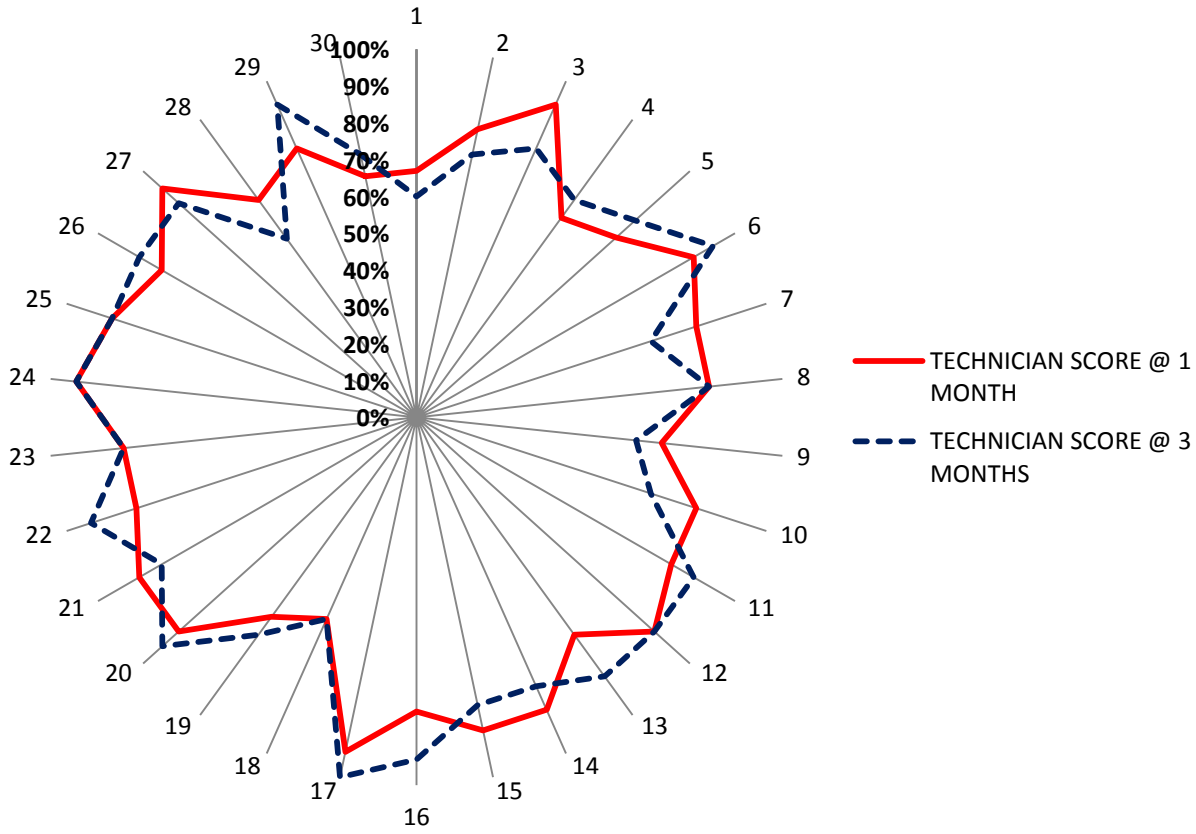

Figure 3: Percentage knowledge performance score and 70 % limit state for 30 technicians at one and three month retention

Figure 4 shows the output from the 15 questions used for the one and three months JKT retention assessment while **Table 2** shows the number of technicians that accurately provided the right answers to the safety critical knowledge questions (i.e. questions **4, 7, 9, 11**, and **12**) and technicians that got it wrong.

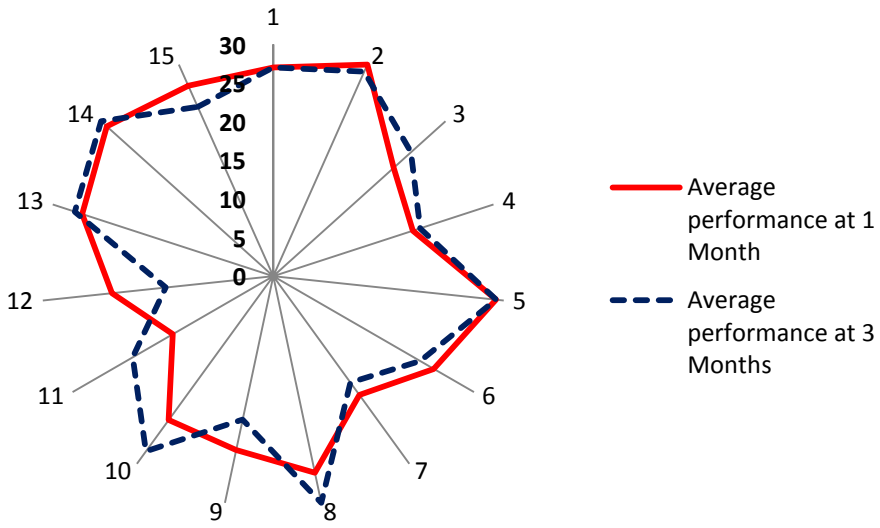

Figure 4: Performance output per knowledge questions at one and three month for 30 technicians

Table 2: Technicians' error rates on safety critical knowledge questions at 1 and 3 month retention

Safety Critical Knowledge Questions	Technicians at 1 Month Retention		Technicians at 3 Months Retention	
	Tech. Right	Tech. Wrong	Tech. Right	Tech. Wrong
Q4. Which one of the following gives the greatest protection when working at height?	**19**	**11**	**20**	**10**
Q7. What should never be done with a fixed vertical safety system, e.g. a wire slider?	**19**	**11**	**17**	**13**
Q9. What is the recommended clearance required for effective use of a fall arrest system containing a 2m energy absorbing lanyard?	**23**	**7**	**19**	**11**
Q11. How often should product being used for regular work positioning be subject to examination?	**15**	**15**	**21**	**9**
Q12. What is the recommended typical life time of a textile product which has sustained regular use?	**21**	**9**	**14**	**16**

The JKT assessment on the five safety critical knowledge questions reveal that **Q7, Q9** and **Q12** showed some increment in the number of technicians that got the questions wrong over the one and three month retention intervals while the number of participants that got **Q4** and **Q11** wrong declined.

Discussions, Practical Implications and Conclusions

The SJT results show 16 technicians with performances ≥70% and 14 technicians at ≤70% at one and three month retention. This indicates that some technicians (typically new or first-time) will struggle to sustain their competency after three months if they are not exposed to some forms of practice after initial rescue and evacuation training. It indicates that the lack of non-routine practice by technicians could lead to skill decay and this study proposes a

mandatory refresher practice drill to sustain technicians' competency. Evidence suggests that for a successful transfer of training and for skill to be retained over a period of time, it is fundamental that the resources and available opportunities to practice and perform the newly acquired skills are present (**Clarke 2002; Salas *et al*. 2006; Burke & Hutchins 2007; Weissbein *et al*. 2010**).

Previous studies have emphasised that in many domains, expert performances are displayed by individuals having more than 10 years of experience, see **Patel & Groen (1991)**. However, **Ericsson et al. (1993)** was keen to point out that a sufficient amount of experience or practice does amount to maximal performance as previously believed. This paper identifies that both new and returning technicians with diverse experiences attained variable performance scores in the SJT and JKT assessments. Therefore, SJT and JKT has the capacity to improve the performances of highly experienced and skilled but yet individually different wind technicians when they embark on an abridged deliberate and routine forms of practice of rescue and evacuation procedures no more than three months after initial training, **(Ackerman 2013)**.

The results from JKT assessment show that 24 wind technicians had average performance scores of ≥70% while 6 technicians had performance scores <70% at one and three months. This result further reaffirms that the retention of knowledge can be sustained longer than skills. It also identifies that wind technicians are capable of maintaining their knowledge base up to three months, (**Lawani *et al*. 2015**). A point of caution however is that too much reliance on high performance scores from knowledge assessment will lead to a false sense of security in terms of overall procedural competence of the wind technicians.

Previous studies have implemented different time intervals in evaluating skill and knowledge retention e.g. from one day to as long as two years; **Wisher *et al.* (1991); Marmie & Healy 1994; Oermann et al. 2011; Kim et al. 2013).** Result from this study regarding skill and knowledge decay at one and three month aligns with studies carried out by **Marmie & Healy (1994)** which recorded statistically significant decay in retention rate within one month and six month retention assessment; and **Oermann et al. (2011)** which showed that CPR skills continued to improve or were maintained with deliberate monthly practice of only six (6} minutes per month. Implementing SJT and JKT forms of evaluation as a low-fidelity and a deliberate practice intervention can potentially improve their performance on safety critical rescue steps before the technicians embark on any form of hands-on refresher training; **(Maagaard et al. 2011**; **Kessler et al. 2011).**

The five safety critical steps (**Table 1**) identified in the SJT assessment based on the rescue and evacuation device are uncued, lack logical procedure and these steps tend to be least likely recalled; **(Lawani et al. 2015; Lawani, 2015)**. This study identified that the uncued safety critical skill steps showed no performance improvement at one and three month retention after initial training. Therefore, the device reported in this paper falls short of

logical, procedural task steps which could be one of the contributory reasons why technicians tend to easily forget these safety critical steps inherent to the device.

Findings from this paper, which are based on primary data, suggest variable rates for skill and knowledge retention at one and three months. It can be inferred that the degree of successful performance of technicians on these assessments are largely dependent on their aptitude, learning and training, experience or the type of practice and instructions previously received. To attain consistency in rescue and evacuation skills, there should be sustained and deliberate practice of such skills that is bespoke.

Safe rescue and evacuation from a wind turbine requires robust procedures to be firmly in place and this study recommends that employers should intermittently evaluate the technicians' training, skills and competence to minimise the effect of skill decay. Likewise, future designs of rescue and evacuation devices should incorporate fewer task steps as this could likely improve retention. Other allied industries like telecommunications, industrial climbing & rigging, scaffolding, and tower crane using rescue devices are also prone to similar retention of rescue skills. This paper concludes that implementing SJT and JKT assessments as an evaluation tool can provide useful information relevant to skill and knowledge retention and for strategic refresher training purposes.

Lessons for worker safety in the broader construction industry; **and implications for international industry practices**

The result from this study suggests that first-time technicians involved in rescue and evacuation training but without the opportunity for routine practice could potentially be vulnerable to accidents even after initial training, i.e. quicker skill decay. This could be curtailed through timely evaluation of their performance on some safety critical rescue steps and selective retraining and mentoring opportunities in order to improve their competency.

This study can potentially inform rescue and evacuation device manufacturers in minimising complex deployment steps; introducing cues and error correction strategies; and simplified instructions in the deployment of the rescue kit. The wider impact of this research is the ability to replicate the SJT and JKT forms of assessment in other height rescue kits used for emergency rescue and evacuation of workers.

References

Ackerman, P.L., 2013. Nonsense, common sense, and science of expert performance: Talent and individual differences. *Intelligence*, 45, pp.6–17.

Adams, J.A., 1987. Historical Review and Appraisal of Research on the Learning, Retention, and Transfer of Human Motor Skills. *Psychological Bulletin*, 101(1), pp.41-74.

Anderson, J.R., 1983. *The architecture of cognition*. Cambridge, MA: Harvard University Press.

Anderson, G., Hughes, C., Patterson, D. & Costa, J., 2017. Enhancing inter-professional education through low-fidelity simulation. *British Journal of Midwifery*, 25(1), pp.52-58.

Annett, J., 1991. Skill Acquisition. In Morrison, J.E., ed. *Training for Performance: Principles of Applied Human Learning*. Chichester, England, 1991. Wiley and Sons.

Arthur Jr., , Benneth Jr., W., Day, E.A. & McNelly, T.L., 2002. *Skill Decay: A comparative assessment of training protocols and individual differences in the loss and reacquisition of complex skills*. Technical: AFRL-HE-AZ-TR-2002-0004. Mesa AZ: AFRL United States Air Force Research Laboratory.

Arthur, Jr, , Day, A., Bennett, Jr, W. & Portrey, A.M., 2013. *Individual and Team Skill Decay: The Science and Implications for Practice*. New York: Routledge.

Arthur, Jr, et al., 2010. The Effect of Distributed Practice on Immediate Posttraining, and Long-Term Performance on a Complex Command-and-Control Simulation Task. *Human Performance*, 23, pp.428-45.

Arthur, J.W. et al., 2007. *Decay, Transfer, and Reacquisition of a Complex Skill: An Investigation of Practice Schedules, Observational Rehearsal, and Individual Differences*. Woburn, MA: Aptima, Inc.

Bohm, W. & Hackl, , 1996. The effect of serial correlation on the in-control average run length of cumulative score charts. *Journal of Statistical Planning and Inference*, 54(1), pp.15-30.

Burke, L.A. & Hutchins, H.M., 2007. Training transfer: An integrative literature review. *Human Resource Development Review*, 6(3), pp.263-296.

Cesta, , Cortellessa, G. & De Benedictis, R., 2014. Training for crisis decision making – An approach based on plan adaptation. *Knowledge-Based Systems*, 58, pp.98-112.

Clarke , N., 2002. Job/work environment factors influencing training effectiveness within a human service agency: Some indicative support for Baldwin and Fords' transfer climate construct. *International Journal of Training and Development*, 6(3), pp.146-62.

Creswell, J.W., 2014. *Research Design: Qualitative, Quantitative, and Mixed Methods Approaches*. 4th ed. Thousand Oaks, California: Sage.

de Vaus, D.A., 2001. *Research Design in Social Research*. London: SAGE publications.

Ericsson, A.K., Krampe , R.T. & Tesch-Romer, C., 1993. The Role of Deliberate Practice in the Acquisition of Expert Performance. *Psychological Review*, 100(3), pp.363-406.

Gillham, B., 2000. *Case Study Research Methods*. London: Continuum.

Hammersley, M. & Atkinson, P., 1995. *Ethnography: Principles in Practice*. London: Routledge.

Hróbjartsson, A. et al., 2013. Observer bias in randomized clinical trials with Observer bias in randomized clinical trials with with both blinded and nonblinded assessors. *Canadian Medical Association,* p. 120744.

Kanfer, R. & Ackerman, P.L., 1989. Motivation and cognitive abilities: An integrative/aptitude–treatment interaction approach to skill acquisition. *Journal of Applied Psychology*, 74, pp.657–90.

Kessler, D.O. et al., 2011. A Randomized Trial of Simulation-Based Deliberate Practice for Infant Lumbar Puncture Skills. *Simulation in Healthcare*, 6(4), pp.197-203.

Kim, J.W., Koubek, R.J. & Ritter, F.E., 2007. Investigation of Procedural Skills Degradation from Different Modalities. In *Proceedings of the 8th International Conference on Cognitive Modeling*. Oxford, UK, 2007. Taylor & Francis/Psychology Press.

Kim, J.W., Ritter, F.E. & Koubek, R.J., 2013. An Integrated Theory of Skill Acquisition and Retention in the Three Stages of Learning. *Theoretical Issues in Ergonomics Science*, 14, pp.22-37.

Kluge, A. & Frank, , 2014. Counteracting skill decay: four refresher interventions and their effect on skill and knowledge retention in a simulated process control task. *Journal of Ergonomics,* 57(2), pp.175-90.

Kluge, A., Frank, B., Maafi, S. & Kuzmanovska, , 2016. Does skill retention benefit from retentivity and symbolic rehearsal? – two studies with a simulated process control task. *Ergonomics*, 59(5), pp.641-56.

Kluge, A., Sauer, J., Burkolter, D. & Ritzmann, S., 2010. Designing Training for Temporal and Adaptive Transfer: A Comparative Evaluation of Three Training Methods for Process Control Tasks. *Journal of Educational Computing Research*, 43, pp.327–53.

Lawani, O., 2015. *Investigating skill decay of wind turbine technicians in emergency rescues*. Thesis (Ph.D.). Glasgow: Glasgow Caledonian University Glasgow Caledonian University.

Lawani, K., Hare , B. & Cameron, I., 2015. Scheduling refresher-based rescue and evacuation training for wind turbine technicians. In Froese, T.M., Newton, , Sadeghpour, F. & Vanier, D.J., eds. *The Canadian Society for Civil Engineering 5th International/11th Construction Specialty Conference*. Vancouver, Canada, 2015. The University of British Columbia.

Lievens, F. & De Soete, B., 2012. Simulations. In N. Schmitt, ed. *Handbook of Assessment and Selection*. Oxford University Press. pp.383-410.

Lievens, F., Peeters, H. & Schollaert, E., 2008. Situational judgment tests: a review of recent research. *Personnel Review*, 37, pp.426-41.

Lievens, F. & Sackett, P.R., 2012. The Validity of Interpersonal Skills Assessment Via Situational Judgment Tests for Predicting Academic Success and Job Performance. *Journal of Applied Psychology*, 97(2), pp.460-68.

Maagaard, M. et al., 2011. Retention of laparoscopic procedural skills acquired on a virtual-reality surgical trainer. *Surgical Endoscopy*, 25, pp.722-27.

Marmie, W.R. & Healy, A.F., 1994. The long-term retention of a complex skill. In F. Healy & E. Bourne Jr, eds. *Learning and memory of knowledge and skills: Durability and specificity*. Thousand Oaks,CA: Sage Publications. pp.30-65.

McCloy, R.A., Campbell, J.P. & Cudeck, R., 1994. A confirmatory test of a model of performance determinants. *Journal of Applied Psychology*, 79, pp.493–505.

McDaniel, M.A. et al., 2001. Use of situational judgment tests to predict job performance: A clarification of the literature. *Journal of Applied Psychology*, 86, pp.730-40.

Meador, D.P. & Hill, R.R., 2011. Modeling Training Effects Using a Human Performance Taxonomy. *Human Factors and Ergonomics Society* , 53(4), pp.391-402.

Motowidlo, J., Dunnette, M.D. & Carter, G.W., 1990. An alternative selection procedure: The low-fidelity simulation. *Journal of Applied Psychology*, 75(6), pp.640-47.

Oermann, M.H., Kardong-Edgren, S.E. & Odom-Maryon, , 2011. Effects of monthly practice on nursing students' CPR psychomotor skill performance. *Resuscitation*, 82, pp.447–53.

Pallant, J., 2011. *SPSS Survival Manual: A step by step guide to data analysis using SPSS*. 4th ed. New South Wales: Allen & Unwin.

Patel , V.L. & Groen, G.J., 1991. The general and specific nature of medical expertise: A critical look. In K.A. Ericsson & J. Smith , eds. *Toward a general theory of expertise*. Cambridge, England: Cambridge University Press. pp.93-125.

Patterson, F., Zibarras, & Ashworth, V., 2016. Situational judgement tests in medical education and training: Research, theory and practice: AMEE Guide No. 100. *Medical Teacher*, 38(1), pp.3-17.

Reason, J., 2008. *The Human Contribution:Unsafe Acts, Accidents and Heroic Recoveries*. 1st ed. London: CRC Press.

RenewableUK, 2014. *Working at Height & Rescue Training Standard*. Training Standard. London: RenewableUK RenewableUK & GWO.

Richardson-Klavehn , A. & Bjork, R.A., 1988. Measures of memory. *Annual Review of Psychology*, 39, pp.475-543.

Sackett, P.R., Schmitt, N., Ellingson, J.E. & Kabin, M.B., 2001. High-stakes testing in employment, credentialing, and higher education: Prospects in a post-affirmative action world. *American Psychologist*, 56, pp.302–18.

Salas, E., Wilson, K., Priest, H. & Guthrie, J., 2006. Salas, E., Wilson, K., Priest, H. & Guthrie, J., 2006. Design, delivery, and evaluation of training systems. In G. Salvendy , ed. *Handbook of human factors and ergonomics*. 3rd ed. Hoboken, NJ: John Wiley & Sons. pp.472-512.

Sauer, J., Hockey, G.R.J. & Wastell, D.G., 2000. Effects of training on short- and long-term skill retention in a complex multiple-task environment. *Ergonomics*, 43, pp.2043–64.

Weissbein, D.A., Huang, J.L., Ford, J.K. & Schmidt, A.M., 2010. Influencing learning states to enhance trainee motivation and improve training transfer. *Journal of Business and Psychology*, 26, pp.423-435.

Whetzel, D.L. & McDaniel, M.A., 2009. Situational judgment tests: An overview of current research. *Human Resource Management Review*, 19, pp.188–202.

Wisher, R.A., Sabol, M.A., Sukenik, H.K. & Kern, R.P., 1991. *Individual Ready Reserve (IRR) Call-Up: Skill Decay*. Technical. Arlington, VA: ARI The U.S. Army Research Institute for the Behavioural and Social Sciences.

Wixted, J.T., 2004. On common ground: Jost's (1897) law of forgetting and Ribot's (1881) law of retrograde amnesia. *Psychological Review*, 111, pp.864–79.

Wixted, J.T. & Ebbesen, E.B., 1991. On the form of forgetting. *Psychological Science, Vol. 2, No. 6*, pp.409-15.

Zierke, O., 2014. Predictive Validity of Knowledge Tests for Pilot Training Outcome. *Aviation Psychology and Applied Human Factors,* Volume 4, pp. 98-105.